MARGINS AND TRANSACTION TAXES IN AN INTRADAY CONTINUOUS DOUBLE-AUCTION FUTURES MARKET

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ABSTRACT

Futures market quotes and transaction prices are derived endogenously in an artificial market with bilateral trading in a continuous double auction. The market participants — speculators, hedgers, and scalpers — have different strategies and reasons for trading futures. Risk-neutral speculators with heterogeneous expectations leverage themselves and try to maximize profit, while being constrained by margin requirements and trading costs. Hedgers provide a fundamental price anchor, and scalpers act as market makers. Emphasis is placed on exchange rules and regulations that govern trading rather than agent learning. The futures exchange imposes real-time gross settlement, margin requirements, and a one-way transaction fee or tax on speculators. Despite a lack of individual rationality and well-behaved demand functions, our model creates a bid-ask spread that, although turbulent, converges to the exogenous cost of trading for speculators and a mid-price that strongly detects the black box Walrasian equilibrium price. In a market with only speculators and hedgers, prices appear to have a lower level of kurtosis, or volatility, when the market is less leveraged, or, in other words, margin requirements are high. The raising of transaction taxes in such a market only serves to reduce trading and increase price volatility. By adding market makers to the model, trading volumes are maintained even in high tax regimes, making the market price more resilient and reducing price volatility.

Keywords: Margins, transaction tax, continuous double auction, futures market, agent-based model, scalpers

INTRODUCTION

Market microstructure emphasizes market design and the mechanics of trading. This paper simulates trading on a futures exchange. Unlike most papers in this genre, this paper ignores the role of information, learning, and rationality, instead investigating a market structure with diverse agents bound by trading rules or traditions. This is similar to the Gode and Sunder (1993) model of zero intelligence agents, where the budget constraint is critical to allocational efficiency. Despite its relative simplicity, this preliminary study may provide insights for market design. Our project is to analyze the presence of liquidity, efficiency, and stability at the aggregate level, without imposing exorbitant assumptions on micro behavior, such as rationality, or the Arrow and Debreu (1954) restrictions.

Most economic theories rest on the premise that aggregate relationships are stable over extended intervals of time. The creation of microfoundations to underlie these aggregate economic stylized facts has relied on maintaining the falsehood that aggregates behave the same

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way as their component parts and that therefore the behavior of the aggregate is attributed to that of some fictional representative agent (Martel 1996).

In the next section, we begin by describing futures trading on the floor of the exchange. There is a discussion of what is meant by liquidity and of how margin or tax policy might impact trader activity and market liquidity. Section 3 explains the model. In opposition to most papers in this genre (Arthur et al. 1997; Farmer and Joshi 2002; LeBaron 2000, 2002), this paper simplifies the trading process by removing information and learning from agent behavior. Speculator expectations are given at the outset and do not change. A continuous double-auction (CDA) market is implemented with real-time gross settlement (RTGS). Trading is derived from simplified but recognizable agent trading rules, which may involve backward-bending demand functions, leveraged trading, short selling, and asynchronous trading. In Section 4, we experiment with some preliminary simulations and suggest ways that notions of liquidity and institutional rules, such as margin requirements, transaction taxes, and RTGS, might be evaluated. Preliminary results on the impact that margins and taxes may have on price volatility are presented. We find that despite the potential for individual instability, market stability is a common trait.

FUTURES MARKET TRADING

Open Outcry

In an *open-outcry* futures market, as described by Silber (1984), all *bids* and *offers* must be announced publicly to the pit through the outcry of buy or sell orders. In particular, no prearranged trades are permitted on futures exchanges. Strict priority is kept, where the highest bid price and the lowest offer take precedence, and this is known as the *inside spread*. Lower bidders must keep silent when a higher bid is called out, and higher offers are silenced when a lower offer is announced, although simultaneous offers and simultaneous bids at the same price can occur. To increase the probability of execution, a trader can raise his bid or lower his offer, and then other traders must remain silent. This rule is designed to insure best execution, in the sense that sales occur at the highest bid price and purchases occur at the lowest offering, and all bids or offers do not live longer than the moment needed to make a transaction.

Scalpers, also known as *locals* because of their exchange membership, are floor traders who trade on their own account and have low transaction costs and more flexible margin requirements than speculators. Like *dealers*, in bond or foreign exchange markets, scalpers regularly quote a bid price at which to buy and an ask price at which to sell, *making a market* and thereby offering to complete orders quickly, typically at a price close to the last price, for those anxious to trade. By inserting this spread between the buy and sell, the scalper thereby receives a profit for providing the service of *immediacy,* which is just one dimension of *liquidity*. Scalpers may also provide *depth* commensurate with the quantity they are willing to buy or sell. While scalpers typically provide liquidity, it is important to note that they can also “consume” liquidity when they liquidate or *offset* positions, by selling at the bid price or buying at the ask price. This reduction in liquidity may cause temporary instability (Schwartz 1988).

An ordinary trader (nonscalper) can either tender his own ask or bid quote that competes with the scalper, called a *limit order,* or accept the price currently quoted in the market, called a *market order.* When a market participant accepts the market bid, he is said to *hit* the bid. When he accepts the market ask, he is said to *lift* the ask. The following example highlighting the choices of a nonscalper who wants to buy contracts is taken from Silber (1984, page 940). A commercial hedger can instruct his *broker* (on the floor) to buy 50 contracts *at the market*, in which case the broker lifts the asks of others in the pit. Alternatively, the commercial hedger can try to buy more cheaply by instructing the floor broker to bid for 50 contracts at the prevailing bid price in the pit. In the first case, the *market order* uses the immediate execution services provided by the offerers in the pit (from scalpers or whomever) consuming liquidity. In the second case, the bid represented by the floor broker can be used by others to sell into, thereby providing liquidity.

Our study is partly to consider how effectively a financial market with asynchronous trading operates without intermediaries, such as scalpers. Often the mismatch between buyers and sellers that typically exists at any given instant is resolved by some agents who are willing to play the role of *market maker* and provide *liquidity*.

Bid-Ask Spread and Liquidity

The academic literature on market microstructure recognizes that the arrival of random traders to buy or sell is asynchronous, and market activities are temporally discrete. This literature treats such moment-to-moment aggregate exchange behavior as an important descriptive aspect of markets (Garman 1976) and has led to many interesting questions, such as: How are market structure and the trading process related to the price process or the valuation of securities? What sort of trading arrangements maximize efficiency? How is information impounded in prices?

There is rarely a single price in microstructure analyses, and the research into the CDA and the various prices derived from this — either quoted, averaged, or actually traded on — are components of the *bid-ask spread*. The size of the spread is an important dimension of *liquidity*. Modeling the spread is an extremely complex matter, given that the markets are composed of numerous *limit traders* (which include dealers and ordinary traders) embedded in a dynamic, interactive environment. Such a system may best be modeled with an agent-based methodology.

The analytical bid-ask spread literature (Stoll 1978; Ho and Stoll 1981) explains the demand for immediacy from the asynchronous arrival of random traders to buy or sell. It is often assumed that dealers participate in every trade, known as a *quote-driven market.* The behavior of the market maker or dealer is typically described as a trader who inserts a spread between the buy and sell and thereby receives a profit for providing the service of *immediacy* in what might otherwise be a fragmented market. This view of the market maker, as a provider of predictable immediacy, was first formalized by Demsetz (1968) and then elaborated on by Garman (1976) and many others. It is generally accepted that the bid-ask spread is representative of the risks faced by the dealer as a result of inventory control and asymmetric information. When scalpers provide for market orders, they profit from impatient traders but lose to traders more informed. It is usually concluded that with competition, the spread is reduced to the dealer's trading costs. This theory has formalized the idea of dealers as being providers of liquidity and controllers of the size of the spread. Inventory control costs are assumed to be reasonably constant over time, while risks of asymmetric information are not (Engle and Lange 1997, page 4). The size of the premium charged by *immediacy providers* to cover these expected costs determines the size of the spread and thereby the extent of illiquidity in the market.

Liquidity is defined in many different ways. If the bid-ask spread reflects the price at which immediacy can be obtained by ordinary investors trading via market orders, then a market is commonly thought of as perfectly liquid if trades can be executed with no cost (O'Hara 1997; Engle and Lange 1997). By this definition, a narrower spread means a more liquid market. This simplified characterization and measure of liquidity has recently gained popularity (see Flemming 2003), although many other definitions have long been debated.

Liquidity is usually said to have four dimensions: *immediacy, width, depth,* and *resiliency*. *Immediacy* refers to how quickly trades can be arranged at a given cost. *Width* refers to the cost of doing a trade for a given size. *Depth* is the size of a trade for a given cost. *Resiliency* refers to how quickly prices revert to former levels after they change in response to large order flow imbalances (see Harris 2003, pp. 398–405).

Liquidity is often described as being supported by a particular group of traders. Market makers are considered the primary providers often endowed with the responsibility of balancing order flow — choosing prices that equate supply with demand. As a key participant in the price discovery process, the market maker acts as a matchmaker, bringing public buyers and sellers together.[1]

Schwartz (1988) argues that too much emphasis has been made of market makers and their spread. While they may be needed in illiquid markets, they are not a necessity for liquidity. Schwartz emphasizes the resiliency dimension of liquidity and argues that more attention should be paid to the manner in which ordinary traders supply immediacy to each other and compete to reduce market spreads with the scalpers (Cohen et al. 1979, page 814). Schwartz (1988) also warns that for market makers to stabilize a market, they must commit capital or inventory risk, and this may become substantial. Injecting liquidity into a system to stabilize prices might also be just as quickly withdrawn at a later date if shortages are incurred or if the market makers seek to rebalance their portfolios.

Alternatively, Bernstein (1987) and Black (1986) emphasize that *noise traders*, with their diverse opinions, help provide liquidity or *resiliency* to a market. Those who trade on noise allow others to trade on information. It is the noise traders who provide *depth, breadth,* and *resiliency* to a market. At the same time, however, noise traders add volatility to prices and push prices into overvaluation or undervaluation, attracting information traders who push prices back to fundamentals. Hence, noise trading actually puts noise into prices, and prices are less efficient. "What's needed for a liquid market causes prices to be less efficient" (Black 1986, page 32). Bernstein argues that this process leads to a curious paradox: "…depth, breadth, and resiliency, in other words are not ends in themselves, but a means to induce information traders to trade. Efficient prices are possible only with noise traders creating inefficiencies by their buying and selling" (Bernstein 1987, page 56). This is similar to the analogy of annealing: the market needs to be heated up and made more liquid in order for the efficient price to be found. It is not true, however, that liquidity is not an end in itself. With the segmentation of market roles into different agents, there are some (such as the managers of markets [e.g., a central bank, a stock or

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1 See Stoll (1985) and Schwartz (1988) for further discussion and references on alternative views of dealers and scalpers.

futures exchange, or an investment bank managing a line of corporate bonds]) who are only concerned with making their market liquid and who leave the price level or efficiency goal up to the informed speculators.

Harris (2003, pages 402–403) has a different view from Bernstein (1987) and from Black (1986). Along more traditional lines Harris argues that liquidity is present when prices return to their "fundamental value"; hence, information is key in his description. He argues that it is the *value trader* who promotes resiliency. Value traders are the informed traders who collect as much information about fundamental values as is economically sensible. Value traders supply liquidity, under his notion, when prices differ substantially from their estimates of value, and they trade in quite large sums that may be held over extended time periods. Harris argues that uninformed traders can have a negative impact on prices because dealers are passive traders and do not have an opinion about fundamentals, and they are unable to distinguish between informed and uninformed traders.

However, Harris (2003, page 394) also argues that liquidity is best described as the object of a bilateral search (i.e., in which buyers search for sellers, and sellers search for buyers). Liquidity is easiest to find when many people on both sides of the market are looking for it at the same time. This reiterates Berstein's and Black's analysis that it is noise traders that make this search easier.

Value traders contribute to mean reversion and *scalpers* provide immediacy, but this may not necessarily be efficient. All these arguments depend on which traders have cash, or leveragability, on hand and are ready to modify their investment exposure at the cheapest possible price, through limit orders, thereby offering liquidity. Following from Schwartz's contra-side orders, it would seem easier to not allocate liquidity to a group of traders (value, noise, intermediary) but rather to state that market orders remove liquidity and limit orders provide liquidity. Included in the limit order category is the dealer bid and ask. These different approaches may be considered in our model.

Margins and Transaction Costs

In a futures market, transactions are promises rather than actual transfers of assets. Each promise to buy or sell a commodity at the future spot date is backed with collateral, which can be held as cash or treasury bills with the exchange (or broker). If it is held as treasury bills, then it can earn a rate of return. A minimum margin (collateral) requirement is specified by the exchange to guarantee the fulfillment of each contract an agent holds, whether long or short. The margin requirement is typically quoted as an absolute value per contract (e.g., for a contract of 5,000 bushels of July wheat on the Chicago Board of Trade [CBOT], the *initial margin* requirement is $1,800 per contract). This amount is usually changed by the exchange during the contract's life; it is increased as the contract approaches maturity or when price volatility increases. A competitive exchange tries to minimize the margin requirement so that it just covers anticipated overnight price changes. For example, if price changes are thought to have even a small chance of moving 10%, then the exchange would like to make sure that traders have margin holdings of at least 10% of the contract value, ensuring contract fulfillment. In addition to margin requirements, a percentage transaction fee is often imposed on round-trip transactions. Brokers, exchanges, or the government can institute this as a tax.

Typically thought of as liquidity augmenting, policies to reduce margin requirements and transaction costs are advocated because they increase the amount of trading in a market, which is often thought to reflect liquidity and reduce price volatility. In opposition, there have been a number of economists who argue that excessive trading can increase volatility. They wish to remove noise trading by raising margin requirements (Shiller 2000; Schlesinger 2000) or imposing a transaction tax (Tobin 1974; Pollin et al. 2001) to reduce *excessive speculation* and price volatility in foreign exchange, equity, and futures markets. There are many debates on whether such policies would increase or decrease extreme price volatility (fat tails in the price distribution). Critics argue that taxes would only increase volatility and cannot stop large price movements from occurring (Davidson 1997). Insights might be garnered by an agent-based modeling approach to these policy debates.

AGENT-BASED MODEL OF A FUTURES MARKET

Model Environment

We present a model of speculators, scalpers, and hedgers in a futures trading pit with *open-outcry* and a CDA trading mechanism. In this simplified model, all trader expectations, although heterogeneous, remain constant in order to place focus on the trading mechanism and the impact of trader budget constraints. This is a partial equilibrium model with two markets: a speculative futures market for grain and a residual money market. The price of money is normalized to 1, and agents operate on their budget constraint, which is a function of their wealth, transaction costs, and futures-contract margin requirements. There is no restriction on short selling. RTGS is implemented such that traders settle with each other and the exchange at their time of trade, rather than waiting until the end of the day.

Margins are implemented in this paper in a simplified manner, although they are still relevant to modern market design. First, we mark-to-market trader positions by using RTGS. Thus, instead of using the close-of-day *settlement price* to calculate margin calls, settlement is adjusted continuously throughout the day, and the settlement price used to calculate margin calls is the average of the bid and ask price, or mid-price. This means that profits and losses transfer hands between the exchange and the traders continuously, removing the risk of accumulated losses and trader default. This payment transfer is called the *variation margin*.

Second, the model analytically simplifies the margin calculation by making the *initial margin* and *maintenance margin* the same and specifying the margin requirement as a fixed percentage of the contract value rather than an absolute dollar value per contract. By using a margin requirement that changes with the percentage change in prices, we get closer to the essence of what the exchange considers in setting the margin.

Given these two margin features, our model offers considerable price and quantity feedback opportunities. Although for an individual, high-risk, speculative trader, marking to market is a cautionary act and reduces counterparty risk, it can also result in a volatile market price the higher the settlement frequency is (Farmer et al. 2004). If traders are on their budget constraints, then they will liquidate some of their position when prices move against them in order to stay within their margin requirements, and this creates backward-bending demand functions, as introduced in the next subsection.

Each type of trader has his own rules for trading. *Speculators* are risk neutral and differ only in their expectation of what the futures price should be and in their wealth. Expectations of the next-period futures-contract price stay constant during the trading period. Being risk neutral, speculators are typically at the corner solutions of their budget constraint, maximizing their futures position (long or short) at every chance they get to trade. There is a one-way fee imposed by the exchange, charged as a percentage of each transaction at the point of sale or purchase. The contract size is perfectly divisible, and prices are always non-negative. Speculators are required to hold a minimum amount of cash in their margin account, which is a percentage of the futures contract value. To safeguard contract fulfillment, the exchange carries out RTGS with *variation margins* imposed on every transaction.

Scalpers are members of the exchange and operate on the floor of the exchange without paying a trading fee. They do not have an opinion on the fundamental price and instead try to buy as low and sell as high as they can. They want to maximize the turnover of buys and sells while minimizing their inventory holding. Scalpers prefer to place limit orders (quotes) and to buy at their bid quote and sell at their ask quote. Scalper activity assists in balancing order flow over the long run, which does promote price efficiency, but it could create price instability in our bilateral CDA, either when they offer liquidity to so-called noise traders or when they are forced to liquidate their own inventory holdings with market orders.

Hedgers play only a limited role in setting up the fundamental demand and supply of contracts in the market. There are only two representative hedgers — one going long and the other going short — the difference being the net hedge. They only place market orders to fill their desired contract positions. The quantity of contracts desired is exogenous to the model and does not change. Once their futures position is attained, they stop trading, and together they leave a net excess demand or supply for the rest of the traders in the market to sort out.

Within the CDA, speculators and scalpers (if included) are selected for a sequence of bilateral trading through random nonreplacement in each round, so that each trader has an equal chance of trading. The hedgers are placed last in this sequence, which represents one round. The intraday period of futures trading has several rounds of quoting or transacting, at the bid or ask price. Trades and transaction prices are registered at each time t.

Speculator's Demand Function

In our model with leveraged speculation, κ represents the limit on how much larger a speculator's futures position — price multiplied by the number of contracts ($p_t x_t$) — can be than a trader's wealth m_t. For example, if $\kappa = 4$, then a trader can have up to 4 times his wealth dedicated to a long or short futures position. In other words, the margin requirement is 25%, $1/\kappa = 0.25$. The collateral kept in the margin account by speculator i is held as either Treasury bills or money, represented here as m_t^i. Money held must be greater than the margin requirement, $m_t^i \geq p_t x_t^i / \kappa$, for the current futures position at all times (to the extent that trading allows). There will be several transaction prices throughout the day, which represent a trade at either a quoted bid p_t^b or a quoted ask p_t^a. If there is not enough collateral in the margin account to meet the margin requirement, then speculator i will have to liquidate his position with an offset purchase or sale at his next turn to trade.

The futures position x_t at price p_t is taken on by the speculator as a contract at time t to sell or buy x units of the underlying commodity at price p_t on the spot or maturity date of the futures contract. Since our speculator does not intend to make delivery on this contract, the purpose of holding this position is to flip the position and profit on price changes. On the basis of price expectations $p^{i,\theta}$ about the next transaction price p_{t+1}, speculator i will decide to go either long or short in futures. If the expected short-term gain does not compensate the cost of trading over the next period:

$$(p^{\theta}{}_t - p_t)\, x_t \leq \varpi\, p_t |(x_t - x_{t-1})| ,$$

then the speculator will hold his current position instead of trading. The trader is myopic, and upon opening a position, there is no consideration of costs incurred for reversing the position.

Each speculator is risk neutral and simply maximizes expected wealth π from t to $t + 1$:

$$\pi^e_{t+1} = \left(p^{\theta} - p_t\right)x_t + m_t \ .$$

The speculator's demand curve is derived in the appendix via linear programming. In summary, speculator i's demand for futures in each period t is a slightly simplified version from Ussher (2004):

$$x^i_t\left(p_t; x^i_{t-1}, m_{t-1}, p_{t-1}, p^{i,\theta}, \kappa, \varpi,\right) ,$$

where:

p_t = Intraday futures market transaction price at time t,

x^i_{t-1} = Previous contract position,

m^i_{t-1} = Previous cash position in margin account following last transaction,

$p^{i,\theta}_t$ = Price expectation p^{θ} of the next futures price p_{t+1} at time t.

$1/\kappa$ = Margin requirement as a percentage of futures position value, and

ϖ = Percentage transaction tax on a one-way trade (paid each way).

A futures demand curve is usually represented as a smooth downward-sloping line from the top of quadrant II to the bottom of quadrant I in the two-dimensional R^2 space in Figure 1. Our model produces a nonlinear demand function as a result of the inherent corner solutions from the risk-neutral speculators' wealth constraints and the regulatory setting of margin limits $1/\kappa$, transaction costs, and RTGS.

Each risk-neutral speculator maximizes the next period's expected wealth by holding money as collateral and buying or selling futures (going long or short in futures). The decision to

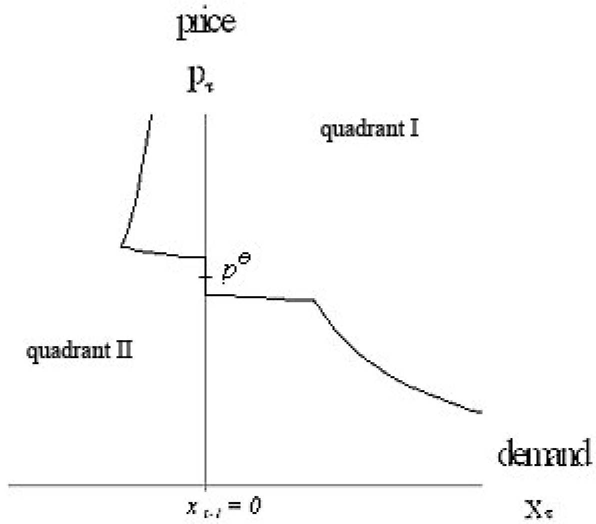


FIGURE 1 A speculator's demand for futures x_t as a function of p_t, with a past zero position $x_{t\text{-}1}$ and price expectations of p^θ

buy or sell futures depends on whether the speculator expects prices to rise or fall, respectively. There is no restriction or disincentive to *short selling* (i.e., selling commodities that one doesn't own). A trader will trade only when price expectations p^θ are far enough away from the actual prices p_t to pay for the one-way transaction costs. Figure 1 has a zero contract position held over from last period. If a speculator currently has a futures position, then margin calls can lead to forced liquidation of the position when prices move against expectations. The possibility of a backward-bending demand function, as in Figure 2, is a result of the collateral px, which underlies demand for x, being priced in the same market.

The speculator will sell (buy) futures if he expects the price to fall (rise) when the slope of the demand function is positive. The demand function has a negative slope when purchasing power is declining from higher futures prices or when collateral is devalued and the speculator must liquidate part of his position to maintain the margin requirement.

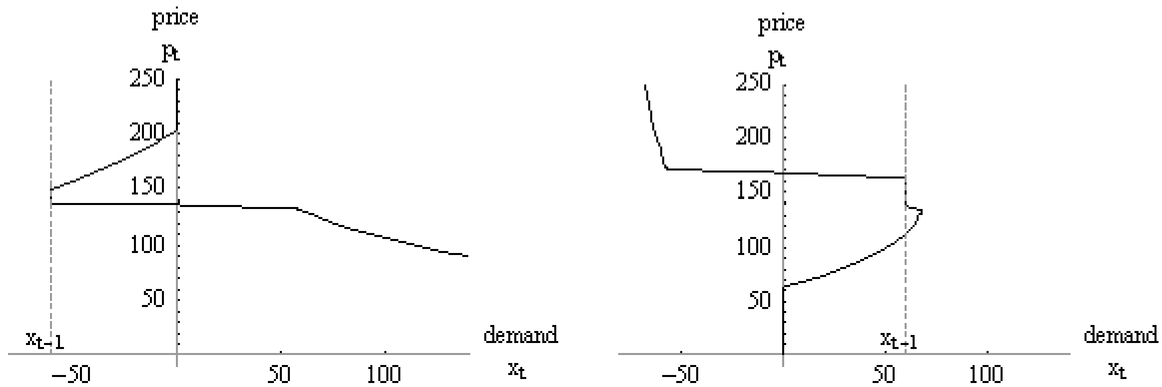
At each t, the variation margin is calculated and net wealth is adjusted. The mid-price p^m is the average of the bid quote p^b and ask quote p^a:

$$p^m = (p^a + p^b)/2 \ .$$

By using the mid-price, the profit or loss is calculated with price changes and paid from the losing agent to the winning agent via the exchange, equivalent to:

$$\left(p_t^m - p_{t-1}^m\right)x_{t-1}^i \ .$$

Each speculator estimates his net wealth at each t, given prices (p^a, p^b, p^m), which determines his decision on how many futures contracts to buy or sell to maximize expected



Speculator is short futures $x_{t-1} = -60$ Speculator is long futures $x_{t-1} = +60$

FIGURE 2 A speculator's demand curve with either a short or long starting position: m_{t-1} = 5,000, p^{θ} = 150, and κ = 2 for each graph

wealth, while at the same time meeting his margin requirement, which is κ multiplied by net wealth. The mid-price is used in accounting for net wealth every period, as long as a position is held.[2]

Bidding and Trading Process

Central to our model is the auction process that simulates the open-outcry on the floor of an exchange, leading to transactions and thus transaction prices. It is a tâtonnement mechanism where both bid and ask prices adjust and where out-of-equilibrium trades take place when an agent agrees to sell contracts to another agent who is bidding for them, or when another agent decides to buy contracts from the agent who is asking for them. This process of quoting and trading is repeated many times, giving each market participant the chance to quote and trade several times and fill his orders. No new information is brought into this process; expectations remain constant.

The competitive bidding algorithm presented here is drawn from several sources. The manner in which speculators compete and how their price expectations interact with the bid-ask spread during the bidding process comes from Chan, LeBaron, Lo, and Poggio (CLLP; see Chan et al. 1998) and Yang (2002). An important modification to their model, apart from keeping expectations constant, is our distinction of risk-neutral speculators with collateral constraints and transaction costs. In addition, we have drawn on another algorithm derived from Silber (1984), emphasizing inventory control and noncompetitive bidding by our scalpers. Hedgers act

2 On the initial purchase of a market order the trader must pay a *variation margin* of $\left(p_t^m - p_{t-1}^m\right)\left(x_t^i - x_{t-1}^i\right)$. Important in this calculation of variation margin is that we keep the distinction between those that profit by buying at the bid or selling at the ask, versus those who are considered impatient and sell at the ask or buy at the bid. When a contract is bought and $\left(x_t^i - x_{t-1}^i\right) > 0$, if it is bought at the bid with a *limit order,* then the variation margin is positive $\left(p_t^m - p_t\right) > 0$. If, however, it is bought at the ask with a *market order,* then the variation margin is negative $\left(p_t^m - p_t\right) < 0$. This results in a transfer of wealth from the trader who is willing to pay for *immediacy* to the trader who gets paid for providing liquidity and *making the market*. The maximization of expected wealth by the speculator takes into account only the expected change in the trade price $\left(p^{\theta} - p_t\right)$, without anticipating whether the transaction is by market order or limit order.

similarly to speculators but only place market orders and hence do not compete in the bid-ask spread. These agents are used to represent fundamental supply and demand.

This asynchronous bilateral bidding process allows two or three traders to participate at any one time, offering or bettering limit order quotations or carrying out market order trades. Agents take turns entering into the inter-dealer market to quote price and quantity, to transact, or to exit. A round is completed when all agents have participated once, with the hedgers coming last. This is repeated for a different random sequence of scalpers and speculators for more than 50 rounds. The repetition or trading rounds represent competition within the price mechanism and help the convergence to equilibrium of market demand and supply.

Auction Algorithm for a Speculator

Half of the bid-ask spread is often thought of as a measure of the cost of executing a market order (the difference between the mid-point price and the payment price). We shall represent this price difference by the lowercase letter s. The size of this spread is actually endogenous to the bilateral trading process. In our model, speculator i's reserve price is his expected price $p^{i,\theta}$ plus the one-way transaction tax ϖp_t.

At times when there is no bid or ask, a speculator will announce his own noncompetitive limit order on the basis of expectations $(1 \pm S\ \varpi)\ p^{i,\theta}$. In this case, S is a percentage of the transaction fee. If S is greater than 100%, then the new limit order will guarantee that a new hit or bid occurs with a demand different from zero.

We present the speculator algorithm with three traders: agent k has the best bid to date, agent j has the best ask to date, and agent i is the new entrant who makes a trade choice under the following four scenarios. Agents j and k are offering the best ask and bid quote to date, respectively, and are scalpers or speculators. Agent i represents a speculator who enters the market and witnesses the current bid-ask spread. Speculators attempt to profit by positioning themselves in each period to maximize short-run profit over every single period t.

- Scenario 1 (Figure 3a). The ask, $p_t^{j,a}$, and bid, $p_t^{k,b}$, currently exist with nonzero offers, at time t.

  1. If $p^{i,\theta} > p_t^{j,a}$, speculator i will post a market order and buy at this ask price — lift the ask quote.

  2. If $p^{i,\theta} < p_t^{k,b}$, speculator i will post a market order and sell at this bid price — hit the bid quote.

  3. If $p_t^{k,b} \le p^{i,\theta} \le p_t^{j,a}$ and $< \left(p_t^{k,b} + p_t^{j,a}\right)/2$, speculator i will post a sell limit order at a price of $(1 + S\ \varpi)\ p^{i,\theta}$ and thus quote his own ask, replacing agent j.

  4. If $p_t^{k,b} \le p^{i,\theta} \le p_t^{j,a}$ and $\ge \left(p_t^{k,b} + p_t^{j,a}\right)/2$, speculator i will post a buy limit order at a price of $(1 + S\ \varpi)\ p^{i,\theta}$ and thus quote his own bid, replacing agent k.

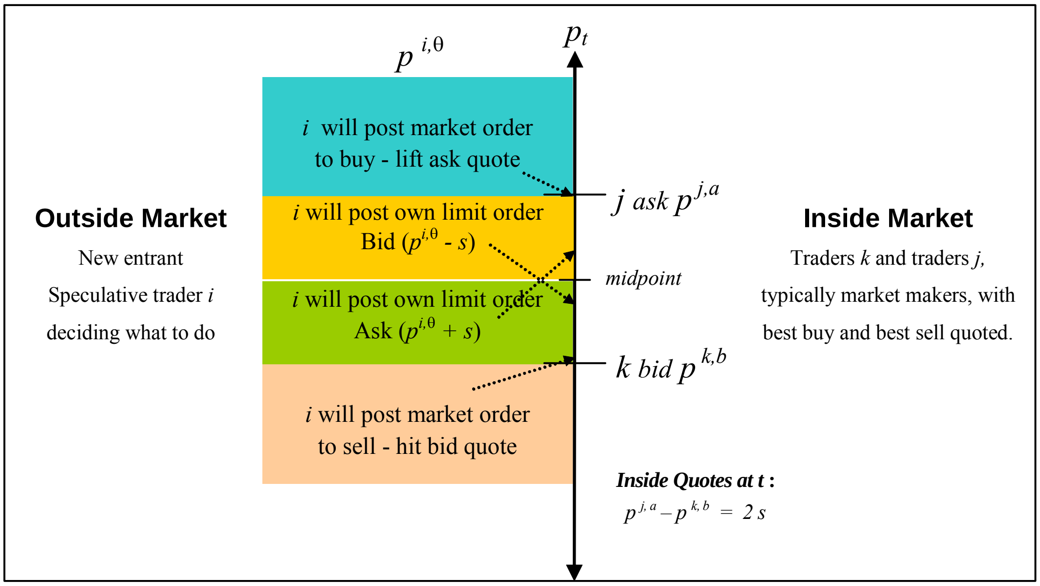


FIGURE 3a Scenario 1, in which both competitive quotes — bid and ask — exist in the marketplace prior to new entrant

- Scenario 2 (Figure 3b). Only the best ask, $p_t^{j,a}$, exists; that is, at $p_t^{k,b}$, the demand to go long must be zero as $\left(x_t^k - x_{t-1}^k\right) \leq 0$.

  1. If $p^{i,\theta} > p_t^{j,a}$, speculator i will post a market order and buy at this ask price.

  2. If $p^{i,\theta} \leq p_t^{j,a}$, speculator i will post a buy limit order $p_t^{i,b}$ at a price of $(1 - S\,\varpi)\,p^{i,\theta}$, but only if excess demand at this price is $\left(x_t^i - x_{t-1}^i\right) > 0$.

- Scenario 3 (Figure 3b). Only the best bid, $p_t^{k,b}$, exists; that is, at $p_t^{j,a}$, demand to go short is zero as $\left(x_t^j - x_{t-1}^j\right) \geq 0$.

  1. If $p^{i,\theta} < p_t^{k,b}$, speculator i will post a market order and sell at this bid price.

  2. If $p^{i,\theta} \geq p_t^{k,b}$, speculator i will post a sell limit order $p_t^{i,a}$ at a price of $(1 + S\,\varpi)\,p^{i,\theta}$, but only if excess demand at this price is $\left(x_t^i - x_{t-1}^i\right) < 0$.

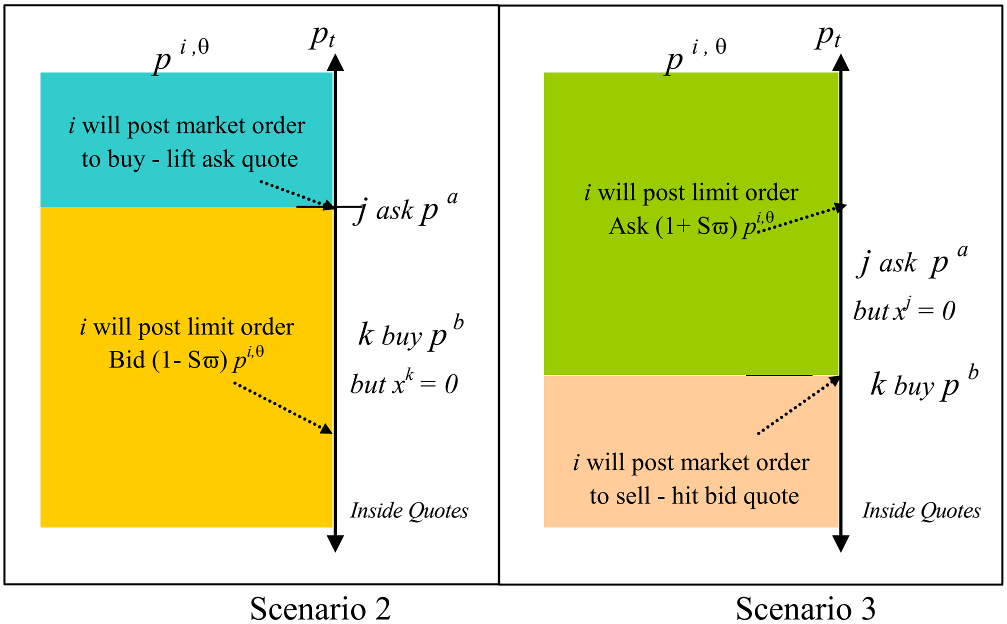


FIGURE 3b Scenario 2, in which an ask but no bid exists prior to new entrant, and Scenario 3, in which a bid but no ask exists prior to new entrant (0 = θ, τ = *t*)

- Scenario 4. No bid or ask effectively exists; that is, at $p_t^{j,a}$, $\left(x_t^j - x_{t-1}^j\right) \geq 0$, and at $p_t^{k,b}$, $\left(x_t^k - x_{t-1}^k\right) \leq 0$.

    1. The new entrant speculator will post a buy and/or a sell limit order at $(1 - S\,\varpi)\,p^{i,\theta}$ and/or $(1 + S\,\varpi)\,p^{i,\theta}$, respectively, as long as his bid is quoted for a buy of greater-than-zero contracts and his ask for a sell of greater-than-zero contracts. If this is not the case, then the current bid-ask remains, even though both traders have zero demand, and entrant *i* exits to join the queue to trade again later.

In our model, under Scenario 2 or Scenario 3, the speculator tendering the best bid (ask) might have had prices move against him; for example, if he was long (short) and prices fell (rose). He may remain offering a bid (ask) price to buy (sell), but at a quantity of zero. Now he wants to offset his position and sell (buy) so that excess demand is less (greater) than zero.

Scenario 2: $\left(x_t^k\left[p_t^{k,b}\right] - x_{t-1}^k\right) \leq 0$, where x_t^k is a function of $p_t^{k,b}$

Scenario 3: $\left(x_t^j\left(p_t^{j,a}\right) - x_{t-1}^j\right) \geq 0$, where x_t^j is a function of $p_t^{j,a}$.

Effectively under Scenario 2 (Scenario 3), agent *k* (agent *j*) falls silent and will eventually be replaced by a new entrant, as long as the new entrant has $p^{i,\theta} < p_t^{j,a}$ (has $p^{i,\theta} > p_t^{k,b}$) and as long as $[x_t^i(1 + S\varpi)\,p_t^{i,\theta} - x_{t-1}^i] > 0$ (as long as $[x_t^i(1 - S\varpi)\,p_t^{i,\theta} - x_{t-1}^i] < 0$); otherwise, agent *k* (agent *j*) will remain. Only when agent *k* (agent *j*) is replaced and exits the market will he be given the chance to satisfy margin requirements by liquidating his position with a market order, in turn, in the random trading round.

This model considerably changes the CLLP rules, which emphasize the manner in which price formation feeds back into the market by agents updating their expectations, to one where price formation feeds back into the market via quantity constraints, margin requirements, and inventory control. This model allows for leveraged trading and short selling and makes the method of settlement a central variable of the model.

Auction Algorithm for a Scalper

In addition to speculators, *scalpers* also participate in the futures open-outcry. Scalpers will try to charge as high a price as possible when selling and as low a price as possible when buying, while still competing with other traders to make a sale or purchase. Only the highest bid and lowest ask are heard in the trading pit. All other noncompetitive quotes must remain silent. Since speculators must compete on price, only speculators are able to narrow the inside-market bid-ask spread. Scalpers balance market order flow by using the *interdealer market* to offset their own inventory excesses. Taking a loss in order to liquidate an unbalanced inventory position forces other interdealer scalpers to also liquidate, and this dries up liquidity in the market until prices are modified.

The scalper algorithm is a simplified version of one stated in Smidt (1985). The objective is to buy at the bid and sell at the ask, maximizing a profit equal to the turnaround of inventory multiplied by the spread, while minimizing inventory risk with a very simplified control mechanism. There is a maximum net inventory ceiling K for each scalper. Netting out the long and short trades by a single agent consolidates the inventory x_t. Scalper inventory must be:

$$-K \leq x_t^n \leq K \quad \text{for scalper } n.$$

In actual markets, K is often as small as one contract and could be different for different scalpers. In our model, all scalpers have the same $K = 10$. When a scalper enters the trading floor from the random sequence, if his inventory is less than his maximum limit K, he always has the right to replace any agent in the *inter-dealer* (inside spread) market by simply matching the agent's quoted bid and ask. This is in contrast to speculators who must offer a better price to replace the agents in the inter-dealer market. If, however, the scalper's inventory is on his limit, then the scalper will place a market order to offload all inventory, if possible. The scalper algorithm is one of simple inventory control:

- New entrant scalper n

  1. If $-K < x_t^n < K$, replace the current market makers and quote both bid and ask at the current quotations $p_t^{k,b}$ and $p_t^{j,a}$, and for quantity $K - x_t^n$, buy, and for quantity $-K - x_t^n$, sell.

  2. If short and $x_t^n \leq -K$, hit the market bid for a maximum $-x_t^n$ and post no quotes.

  3. If long and $x_t^n \geq K$, lift the market ask for a maximum $-x_t^n$, and post no quotes.

The dealer inventory control model outlined here, where a scalper will choose to make a market order rather than change his limit order prices, is in contrast to most accepted inventory control models such as Garman (1976) and Amihud and Mendelson (1980). These authors present dealers as changing their bid and ask to induce an imbalance of incoming orders, in order to reduce inventory. Hasbrouck (2003) questions this latter model and claims that as a general rule, most empirical analyses of inventory control refute this method of changing the quote for inventory control. He argues that a dealer who would pursue the hypothesized mechanism would be signaling to the world at large his desire to buy or sell. This would put him at a competitive disadvantage (Ibid 2003, p. 78). Our simplified mechanism does not touch on information signaling, yet it does avoid this specific criticism.

Auction Algorithm for a Representative Hedger

Hedgers are only concerned about filling their expected sales or purchases at the spot date via market orders in futures. They always come last in each round of the random sequence of speculators and scalpers.

- Hedger scenario

  1. The future purchaser of the commodity at spot, agent *q,* will lift the ask, $p_t^{j,a}$, for the maximum ask quote quantity, until the market buy order is filled, $x_t^q = x^{q*}$.

  2. The future seller of the commodity at spot, agent *r,* will hit the bid, $p_t^{k,b}$, for the maximum bid quote quantity, until the market sell order is filled, $x_t^r = x^{r*}$.

Since speculators and scalpers do not usually offer large size contract lots, it may take several rounds for our hedgers to finalize their purchases or sales. The hedgers contribute so-called *fundamentals* to our speculative market.

Trading Sequence

The setup for trading begins with a random ordering of 60 speculative agents and, when included, 10 scalpers. The two representative hedgers come last in this sequence, which, once completed, is called a trading round. Speculators have equal endowments and heterogeneous expectations taken from a symmetric distribution with a mean p^{θ} of 150. Speculators come together, along with hedgers and scalpers, in bilateral trades to create a CDA.

Two randomly selected traders begin with market quotes set at $p_0^b = 100 : p_0^a = 110$. A new entrant, randomly selected from the remaining traders (not a hedger), enters the floor to either accept or better the prices quoted. If a bid or ask is accepted, a trade is done and a transaction price p_1 occurs for, say, a market order by the new entrant. If, instead, the entrant replaces a bid or ask or both, then a new set of quotations $p_1^b : p_1^a$ (bid : ask) is created, with no transaction price. A sequence of quotes, and transaction prices, is generated during the trading round, with only transaction prices and volumes registered. Repeating the round, drawing a new random sequence of speculators and scalpers each time, creates an interday trading session.[3] This trading sequence is summarized here:

1. Speculators are initialized with initial wealth and random price expectations with a mean of 150. Two randomly selected speculators or scalpers begin with initial quotes of $p_0^b = 100 : p_0^a = 110$ and their respective buy and sell quantities (which may be zero), given their expectations.

2. The random sequence of speculators and scalpers to enter the market with nonreplacement is determined, with hedgers coming last.

3. With one or two agents quoting a bid-ask spread, the new entrant can either submit a new bid or ask, accept the existing bid or ask, or hold (pass).

4. A transaction occurs when the existing bid or ask orders are accepted and the transaction price is recorded accordingly. The transaction is the minimum of the quantities proposed for exchange by each bilateral trader.

5. At each point, mid-point prices are used to calculate speculator budget constraints in real time. On the basis of the past transaction price, each agent's wealth is updated, taking account of all margin calls (profits and losses).

6. Steps 3 through 5 are repeated for n times, where n = number of traders (one round).

7. Steps 2 through 6 are repeated for N times, where N = number of rounds.

8. The final market price is recorded as the last transaction price for this trading session.

The CDA bilateral search and trade algorithm is similar to a repetitive annealing process where the market is heated up through turbulent trading (when margins are low). This might be representative of a hot or liquid market, and this is warranted in order for the equilibrium point to be found. If traders become satisfied with the price and reduce their trading, then the market cools and converges to its fixed price or the efficient market price. But once the market cools, it becomes brittle, and a single trader can disrupt the price with a new quote $(1 \pm S\ \varpi)\ p^{i,\theta}$, causing a credit crunch and trading volume increases. The market heats up again, and the process is repeated.

SIMULATION OF INTRADAY TRADING

In creating a market that consists of highly speculative individual agents who are inherently unstable because of their leveraged positions and settlement constraints, we wish to discover how robust and stable our market is as a whole, given the regulatory framework of

[3] In this paper, we stop at this point. But if one session was considered to be one period of constant expectations, in between the updating of expectations, then such trading sessions, when strung together, could be seen as a day of trading.

transaction taxes and margin requirements. With the imposition of no changes in agent expectations, we focus our analysis on the impact of margin calls and trading volatility on price formation. This is quite separate from the volatility that comes from expectations and information issues. We will consider how efficient trading is in converging to a stable equilibrium price that equates aggregate supply and demand. In addition, we will measure the presence of extreme price movements by looking at the kurtosis of our price distribution. This measure of volatility is most relevant to exchange governance that tries to maintain fair and orderly markets.

Simulation for 60 Speculators, Two Hedgers, and No Scalpers

We begin by simulating a CDA with just speculators and hedgers to consider how speculators alone can effectively replace formal market intermediaries, as suggested by Schwartz and Economides (1995). We use 60 speculators with the same wealth and randomly designated expectations drawn from three different normal distributions. All have a population mean of 150 and a standard deviation, σ, of either 1, 2, or 5. In this paper, we have used only one realization for each simulation,[4] where the 60 agents together have a sample mean of 150.4, a standard deviation of 2.7, and a kurtosis measure of 4.7. The following parameter trials included a tax of either $\varpi = \{0.1\%, 0.5\%\}$ on each one-way transaction and a margin requirement of either $1/\kappa = \{100\%, 33\%, 25\%\}$. All plots below are by transaction dates; hence, competitive quote changes do not show up when the bid-ask spread is narrowed through new limit orders. Only when a market order or purchase occurs are the bid-ask, mid-point, and transaction prices recorded at time t. Figures 8 and 9 (which appear later) actually show whether the trade took place at the bid or the ask.

Figure 4 shows a market with only speculators. The lines connect prices over time: bid, ask, and p^*; this is the Walrasian equilibrium price solution at time $t = 0$, given expectations, wealth, and the net hedge. While the bid-ask spread is usually converging through competitive quotes, the large swings outward by the bid-ask spread are due to the exogenous prices $(1 \pm S\,\varpi)\,p^{i,\theta}$, limit orders that new entrants get to yell out when one of the inter-spread dealers is offering a zero-quantity bid or ask that they want. In these simulations, $S = 8$.[5] The only difference between the two graphs in Figure 4 is the decline in the margin requirement from 100% to 33.3%.

In Figure 4**,** as with all our simulations, the CDA bid-ask spread quickly detected the Walrasian equilibrium price of 151 despite starting with bid-ask quotations of 100:110.[6] There was a narrowing of the spread as speculators competed with each other, but it never got smaller than the transaction costs, ϖp_t, per unit x. When the aggregate desired demand across all agents in the market as a function of the ask approximated the aggregate desired supply as a function of

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4 A full Monte Carlo of our model must be completed before conclusive results can be obtained. The results shown here are only preliminary, but they nevertheless show the potential of this type of analysis.

5 We also used $S = 1.5$, which resulted in the same average price, except that the market was very slow to equate demand and supply.

6 Given the relative symmetry in our wealth-weighted market expectations and given the small net hedge in the market ($x^{r*} - x^{q*} = 5$), this may be expected, but it can only be tested with further investigations across different initial conditions.

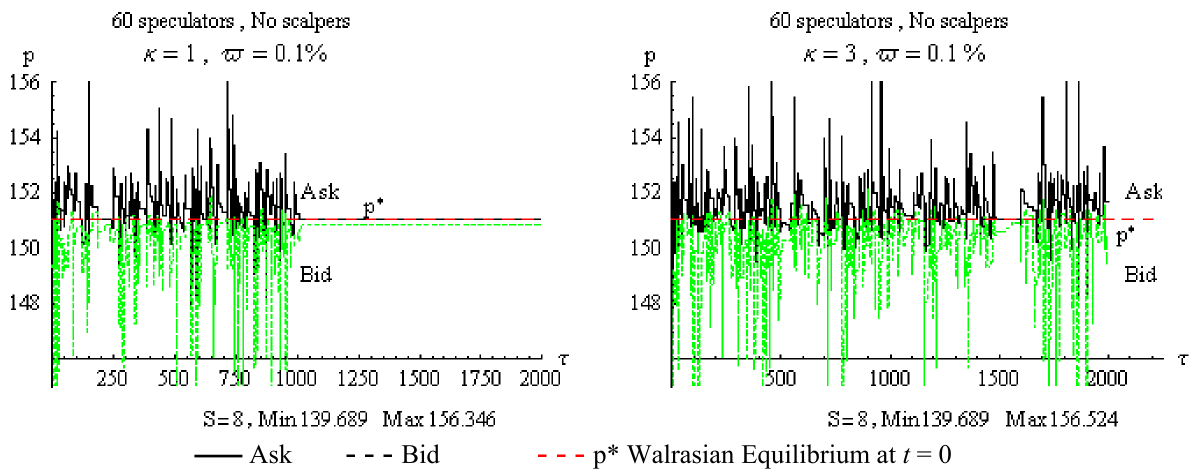

FIGURE 4 CDA bid-ask quotations at each transaction (margin requirements are 100% versus 33%)

the bid, then the bid-ask spread and mid-price were more likely not to change, as in Figure 4 for $\kappa = 1$ or 100% collateral. During these periods, the order flow is kept balanced in aggregate, as most speculators are satisfied and stop trading and as only very small trades occurred between two active traders post-$t = 1{,}000$, as seen by their trading positions in Figure 5. These two traders kept trading longer than their peers because their expectations were very close to $p^*(1 \pm \varpi)$ within the bid-ask spread. This also occurs when taxes are high (see Figure 7, which appears later).

The leverage positions, or contract value relative to wealth, of our 60 speculators are shown individually in Figure 5 for the two simulations with either 100% or 33% margin requirements. Traders who hold a contract position must be either long or short, which will show up as either positive or negative on the vertical. There is always a net zero-sum of contracts in a derivatives market. In our simulation with no leverage and $\kappa = 1$, contracts as a proportion of wealth appear to be relatively steady. In this market, trades are small, and most agents remain in the same or a similar position, even prior to $t = 1{,}000$. This is quite different when the margin requirement is reduced to 33%, $\kappa = 3$, for both Figures 4 and 5. Fewer agents are satisfied with their position as a larger number of traders remain below their leveraged limit and as more trading takes place.[7]

In both simulations, those agents with the more extreme price expectations will spend most of their trading time on or close to their limit — more so than those with “more accurate” price expectations (i.e., expectations that are closer to p^*). Although promoting leveraged trading by reducing the margin requirement stimulated trade activity, it did nothing to the average or standard deviation of the mid-price (both simulations approximated a mean of 151 and standard deviation of 1).

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[7] For trading points $t = 100$ to $t = 1{,}000$, the average trade when $\kappa = 1$ was $0.08x$ contracts. This compares to an average trade volume of $6x$ contracts when the margin is reduced to 33%, $\kappa = 3$.

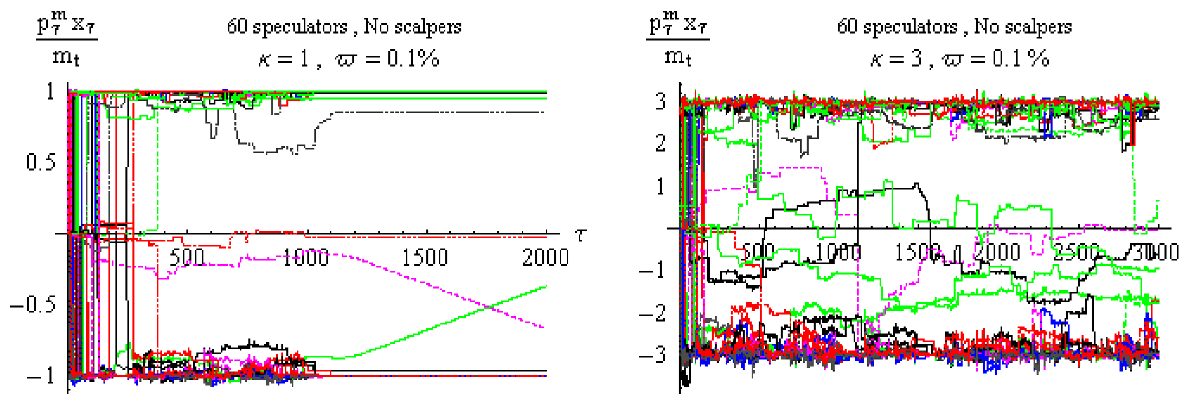

FIGURE 5 Leverage position by each speculator over time (long is positively leveraged, and short is negatively leveraged; margin requirements are 100% versus 33%)

Within our simple model, there is some support for Friedman's (1953) Darwinian suggestion that speculation is efficient because the noise speculators die out and fundamental speculators prosper. This argument is often used in policy circles for the reduction of margin requirements to leverage those traders with information. This assumes that there is only one right price, which is the case in our model, represented by p*. Our model confirms, as shown in Figure 6, that those traders with expectations furthest away from p* do lose money trading. Despite all trader expectations being drawn from a population with a mean of 150, the aggregate income for the group of 20 speculators with a population standard deviation of $\sigma = 5$ is shown to decline much faster in the lower margin environment of $\kappa = 3$ than $\kappa = 1$. The agents with the least noise (smallest dispersion) of expectations around the population mean have greater capital gains because they are more likely, as a group, to be paid for providing immediacy (placing limit orders rather than market orders), and this compensates their cost of trading.

We experimented with lowering the margin requirement from 100% to 25%, raising the transaction costs of trading from 0.1% to 0.5%, and comparing a market without and with scalpers. This was done for a group of 60 speculators and two hedgers with the same wealth and expectations for each simulation. Table 1 shows results for single trace runs of each scenario. In each column, the kurtosis of the mid-price is given first, then the median of the bid-ask spread as a percentage of the mid-price is presented in brackets. We chose mid-price kurtosis since this is representative of the price volatility relevant to the exchange in setting the margin requirement (see Ussher 2004) and since both kurtosis and the bid-ask spread may be considered as measures of liquidity in terms of price resiliency or cost of transacting, respectively.

This evidence, although anecdotal prior to a proper Monte Carlo analysis, suggests that in a market with no scalpers, lowering the margin to 25%, or $\kappa = 4$, may lower the median bid-ask spread and increase the price kurtosis, the more so when taxes are high. The time series of this simulation for prices and leverage is presented in Figure 7. By increasing the costs of transacting, we again reduce trading activity, despite the low margin requirement.[8] Trading is quite orderly, as shown by the leverage time series, with bursts of activity when prices readjust. In the price

8 Under a regime of $\kappa = 4 : \varpi = 0.1\%$, the average trade was 8 contracts, whereas for $\kappa = 4 : \varpi = 0.5\%$, it was 3.6 contracts.

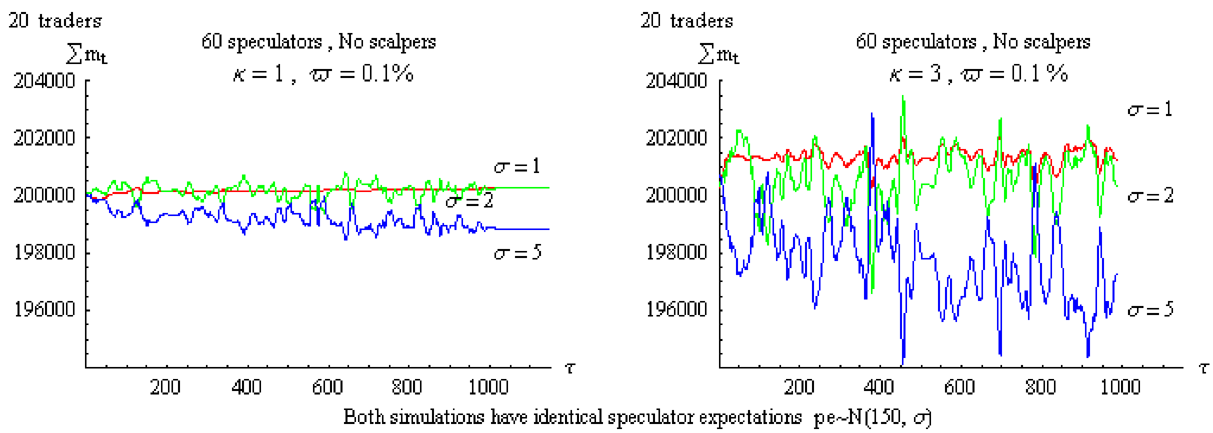

FIGURE 6 Aggregated wealth of each group of 20 speculators, smoothed with a 15-period moving average (margin requirements are 100% versus 33%)

TABLE 1 Measures of *liquidity* from four simulations across different tax rates, margin requirements, and scalpers or no scalpers[a]

	κ			
	No Scalpers		10 Scalpers	
ϖ	1	4	1	4
0.1%	11	20	11	6
	(0.5)	(0.2)	(0.4)	(0.9)
0.5%	23	35	4	5
	(0.5)	(0.5)	(0.5)	(0.8)

[a] Values are kurtosis of mid-price and, in brackets, the median of the bid-ask spread as a percentage of the mid-price. All statistics drop the first 100 price realizations and are from $t = 100$ to $t = 1{,}000$.

series graph, we see that the bid-ask spread is still ϖp and that this tends to flatline more often with the higher tax. This explains the higher price kurtosis value of 35 versus 20 for the same margin requirement, as kurtosis is a measure of the peakness of the price distribution. With the higher tax, a larger number of speculators remain below their leverage limit than when the tax is 0.1%. The CDA tâtonnement price process still detects the Walrasian price, but the mid-price is not as closely matched post-$t = 1{,}500$.

The market without scalpers appears to suggest that transaction taxes will increase the level of kurtosis in a market. This may support Davidson's (1997) claim that a Tobin tax will not

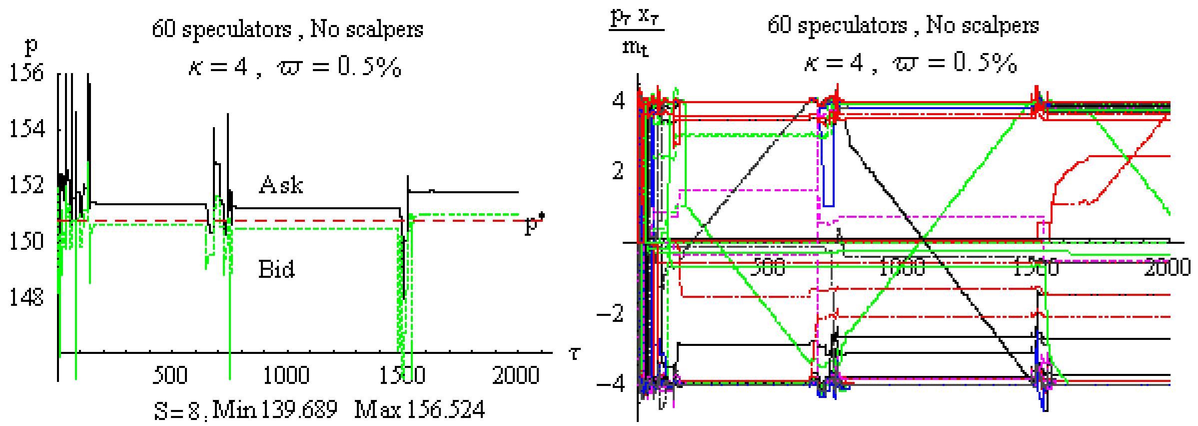

FIGURE 7 Prices and leverage positions for speculators (margin requirements are κ = 4 and tax ϖ = 0.5%)

reduce price volatility but will only reduce market liquidity. In our highly leveraged speculative market, it is interesting to see just what causes volatility, as it has nothing to do with changing price expectations. We shall consider in detail the increase of price volatility from $t = 640$ to $t = 780$ in Figure 8 for the same high-tax, high-leverage market. The size of the black and red dots are representative of a log transformation of the trade size. A black dot is a market order by a speculator to either buy at the ask because he expects prices to rise, or to sell at the bid because he expects prices to fall. A red dot represents a liquidation of a position in order to meet margin requirements and pay for losses following an adverse price change. A liquidation trade is usually on the backward-bending part of the demand function. Since most traders have already taken up their position on the basis of expectations, a lot of the trades that take place are red dots. Prior to $t = 650$, transactions were randomly distributed between the bid and ask, and trade size averaged around 1.2 contracts, with the spread equivalent to the transaction cost, 0.5% of the price.

In studying the above price destabilizations, we have found that buys usually follow buys and sells follow sells. Following what Hasbrouck (2003, page 13) noted for stock market data, trades at the bid tend to maintain trades at the bid, and trades at the ask maintain trades at the ask. In our model, this has nothing to do with expectations formation or trend following behavior; rather, it is due to collateral constraints causing credit crunches and the forced search for immediacy through market orders due to margin calls. A sudden downward bid is not brought back up but rather stays for a time at that low level. The trades at the low bid are followed by more price transactions at that low bid, despite expectations having not changed.

While a Tobin-like tax appears to add price volatility to our speculative market without scalpers, it may be a possible to use this policy to stabilize markets with scalpers, as seen in Table 1. In these simulations, all scalpers have the same inventory limit of K = 10 each. Scalpers are excluded from holding margin or paying transaction costs, as they are presumed to be local exchange members and do not go through brokers. This allows them to provide immediacy even when taxes are high. Figure 9 is a section of time series for two simulations with low versus high tax regimes — 0.1% versus 0.5% on a one-way trade. The grey trades are market orders done by scalpers. Scalpers will place a market order only when their inventory has reached its limit of K = 10; at all other times, scalpers provide limit orders at the bid and ask (all limit orders are the counter trade to market orders).

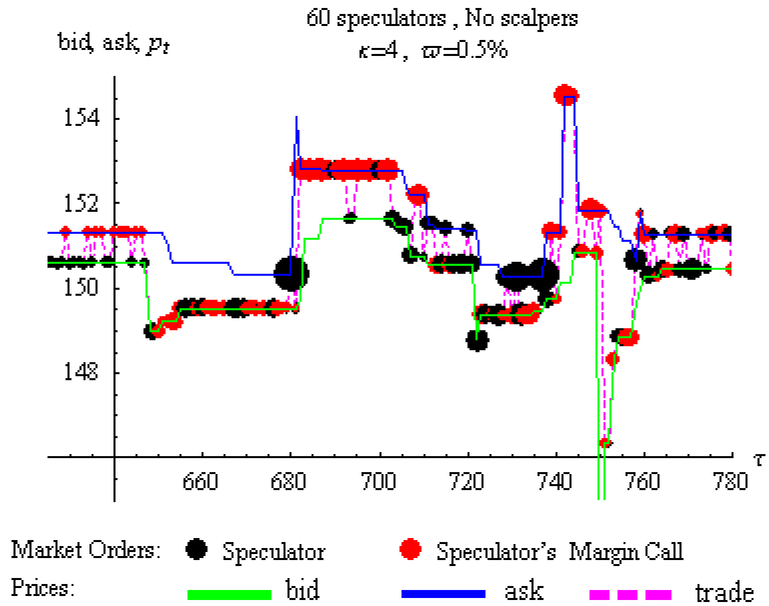

FIGURE 8 Prices and trade size by speculators and hedgers (trades are market orders only).

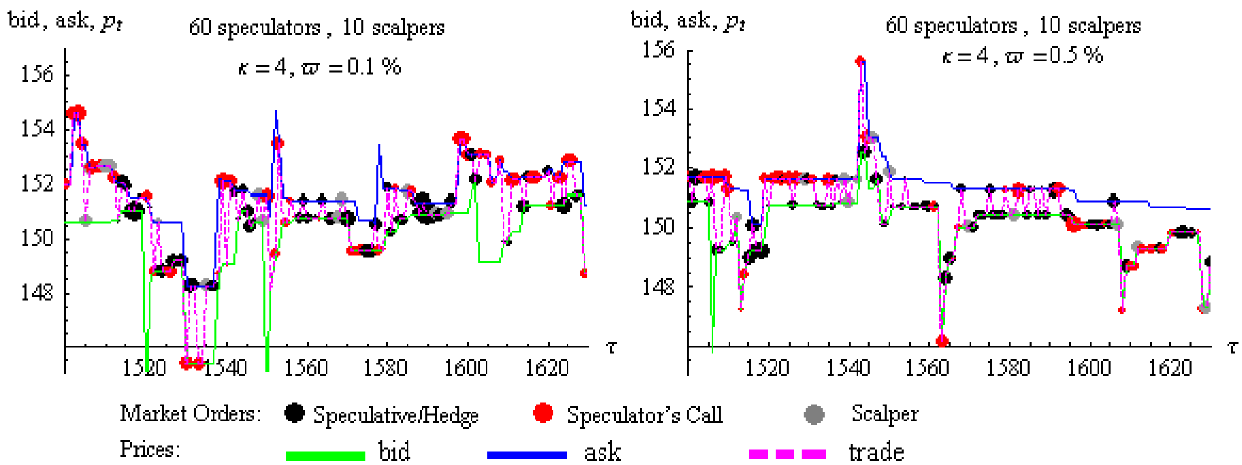

FIGURE 9 Prices and trade size by speculators, hedgers, and scalpers (who make market orders only)

An interesting result from introducing scalpers is that both market prices and activity are less sensitive to changes in the tax rate. Unlike the case with no scalpers, an increase in transaction taxes from 0.1% to 0.5% did not reduce trade activity and trade size in our market with scalpers. It also did not increase the average bid-ask spread, nor the level of kurtosis. While the lowest spread in each simulation with scalpers reflects the low or high tax rate ϖp, the average and median bid-ask spread in the two simulations are very similar.[9]

As specified by the model, scalpers do not narrow or determine the size of the spread, given their overly simplistic trading rules. Instead, myopic speculators determine the narrowness to which the bid-ask spread converges on the basis of their one-way cost of trading. Scalpers, who have no opinion about fundamental prices, will provide liquidity not only to those traders who stabilize markets but also to those traders who destabilize markets. Scalpers appear to not only maintain the bid-ask spread but also indirectly widen it when a *noise* or uninformed trader trades. Scalpers are ready to accommodate such prices. Scalpers may widen the spread even more by reversing their own excessive inventory position from accommodating the "uninformed trader," lifting or hitting the opposite side of the market, creating a zero limit order, and leading to a widening of the spread again. This will mean that the mid-price may be mean-reverting, but the spread initially widens on both sides before narrowing.

However, the larger bid-ask spread in scalper markets does not seem to indicate less liquidity. Instead, price resiliency (low kurtosis) is improved, even in markets with higher transaction costs. Scalper markets might be considered to be more liquid if one considered volume as an indicator of market liquidity or the proportion of speculators below their leverage limit and desiring to trade, as in Figure 10. By exempting market makers from a Tobin tax, this policy might still be successful in removing noise traders, but not at the cost of liquidity and less price resiliency.

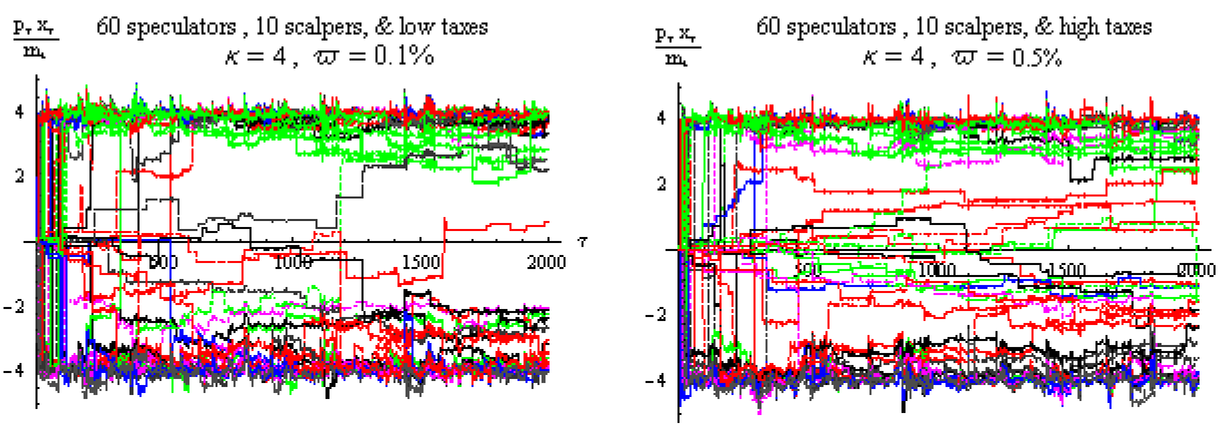

FIGURE 10 Leverage positions for speculators in a market with margin requirements of κ = 4 and scalpers (comparison of 0.1% versus 0.5% transaction tax)

9 For the simulation with 10 scalpers and $\kappa = 4$: $\varpi = 0.1\%$, the mean and median bid-ask spreads as a percentage of price were 0.92 and 1.3, with a minimum of 0.11. For the simulation with 10 scalpers and $\kappa = 4$: $\varpi = 0.5\%$, the mean and median bid-ask spreads as a percentage of price were 0.8 and 1.2, with a minimum of 0.5.

CONCLUSION

This attempt to unpack the Walrasian black box of a speculative futures market has shown that even with the inclusion of leveraged trading, short selling, RTGS, and transaction costs, our market is ultimately stable and reverts to the Walrasian equilibrium price in the long run. A market of speculators with diverse expectations and no market makers will produce a competitive bid-ask spread that fluctuates and often narrows to the cost of transacting ϖp. Adding market makers, or scalpers, however, does create greater price resiliency and may allow for policies that raise transaction costs without adding to market price volatility.

Margins and transaction taxes directly affect the distribution of market orders to limit orders for a fixed distribution of expectations. Without scalpers, lowering the margin requirement increases the sensitivity of demand to price changes and increases the degree of trading activity in the market.

When no scalpers are present, speculators with expectations that are closer to the long run price p^*, especially those within the tax threshold, gain from trading as a result of their ability to play the role of market maker and earn a spread from the noisier traders. The greater the leverage that is allowed in the market, the more impoverished the noise traders become. This follows Friedman's (1953) Darwinian process that low margins quickly sort out the "smart" traders from the "noisy" ones. A larger transaction tax can increase the peakness and fat tails of the price series, making it difficult for exchanges to use the observed probability of prices to set margin requirements. An increase in the tax threshold increases the number of speculators who compete to offer limit orders, which does tend to stabilize prices despite the higher kurtosis. While prices may be more stable in this market, they are less resilient (higher kurtosis).

When scalpers are included in the trading mix, the bid-ask spread is wider, order flow is turbulent, and trading volume is much greater. Despite the larger spread, this may be characterized as a more liquid market, and mid-prices are dramatically more resilient. Changing transaction taxes has less impact on both trade activity and price volatility. In this market, raising taxes can accomplish the goal of impoverishing traders with expectations far away from p^* without adding to extreme price movements or being detrimental to liquidity.

APPENDIX

The risk-neutral speculator maximizes next period's expected wealth (1). The first four of our boundary constraints represents the limit on a speculator's investment by the margin requirement when one is short in futures (2) and (3) versus the extent to which futures can be bought long (4) and (5). We have two each of these restrictions to take into account the one-way tax on both buys and sells $\varpi\, p_t|(x_t - x_{t-1})|$ for speculator i. If the transaction tax is positive, then this boundary constraint will be slack. This dual tax restriction also impacts the budget constraint (6) and (7). The bankruptcy conditions (8) through (12) stop money wealth from going below zero.

For speculator *i*:

Maximize:

$$\pi_{t+1}^{e} = \left(p^{\theta} - p_t\right)x_t + m_t \tag{1}$$

Subject to:

$$p_t x_t \geq -\kappa\left[\left(p_t - p_t^m\right)x_{t-1} + \left(p_t^m - p_t\right)\left(x_t - x_{t-1}\right) + m_{t-1} - \varpi\ p_t\left(x_t - x_{t-1}\right)\right] \tag{2}$$

$$p_t x_t \geq -\kappa\left[\left(p_t - p_t^m\right)x_{t-1} + \left(p_t^m - p_t\right)\left(x_t - x_{t-1}\right) + m_{t-1} + \varpi\ p_t\left(x_t - x_{t-1}\right)\right] \tag{3}$$

$$p_t x_t \geq \kappa\left[\left(p_t - p_t^m\right)x_{t-1} + \left(p_t^m - p_t\right)\left(x_t - x_{t-1}\right) + m_{t-1} - \varpi\ p_t\left(x_t - x_{t-1}\right)\right] \tag{4}$$

$$p_t x_t \geq \kappa\left[\left(p_t - p_t^m\right)x_{t-1} + \left(p_t^m - p_t\right)\left(x_t - x_{t-1}\right) + m_{t-1} + \varpi\ p_t\left(x_t - x_{t-1}\right)\right] \tag{5}$$

$$m_t \leq \left(p_t^m - p_{t-1}^m\right)x_{t-1} + \left(p_t^m - p_t\right)\left(x_t - x_{t-1}\right) + m_{t-1} - \varpi\ p_t\left(x_t - x_{t-1}\right) \tag{6}$$

$$m_t \leq \left(p_t^m - p_{t-1}^m\right)x_{t-1} + \left(p_t^m - p_t\right)\left(x_t - x_{t-1}\right) + m_{t-1} + \varpi\ p_t\left(x_t - x_{t-1}\right) \tag{7}$$

$$0 \leq \left(p_t^m - p_{t-1}^m\right)x_{t-1} + \left(p_t^m - p_t\right)\left(x_t - x_{t-1}\right) + m_{t-1} - \varpi\ p_t\left(x_t - x_{t-1}\right) \tag{8}$$

$$0 \leq \left(p_t^m - p_{t-1}^m\right)x_{t-1} - \left(p_t^m - p_t\right)\left(x_t - x_{t-1}\right) + m_{t-1} - \varpi\ p_t\left(x_t - x_{t-1}\right) \tag{9}$$

$$0 \leq \left(p_t^m - p_{t-1}^m\right)x_{t-1} + \left(p_t^m - p_t\right)\left(x_t - x_{t-1}\right) + m_{t-1} + \varpi\ p_t\left(x_t - x_{t-1}\right) \tag{10}$$

$$0 \leq \left(p_t^m - p_{t-1}^m\right)x_{t-1} - \left(p_t^m - p_t\right)\left(x_t - x_{t-1}\right) + m_{t-1} + \varpi\ p_t\left(x_t - x_{t-1}\right) \tag{11}$$

$$m_t \geq 0 \tag{12}$$

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